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The Center for Computer-based Behavioral Studies (CCBS) ~~on the UCLA campus~~ is designed ~~and will be developed~~ to overcome a number of ~~the~~ methodological limitations blocking significant research advances in~~, and behavioral sciences contributions to,~~ the study and analysis of national policies and problems. The Center is to be designed around a time-shared computer system ~~that will make its informational and technological resources~~ available to behavioral scientists and policy analysts ~~located~~ at widely dispersed university and research centers~~, offering them new and powerful~~ research, policy planning, and educational ~~tools.~~ A number of ~~these~~ tools for studying and analyzing the behavior of individuals, groups, and social-political units ~~are~~ will ~~specifically relevant to~~ help bridge the ~~enormous~~ gap ~~that continues to exist~~ between the policy analyst and the behavioral scientist. An essential part of the development of these broad methodological and technological areas is an ongoing program of substantive research on bargaining and conflict resolution behavior relevant to political crisis management. With the three areas of development (laboratory gaming and simulation research, inductive data analysis, and data resources management) sharing a common and systematic base of operation, the potentials for mutual support among them will be substantially enhanced. Central to all ~~of~~ these activities are plans based on ~~a number of~~ highly integrated software systems, hardware configurations, and laboratory design and equipment requirements, stemming from ARPA-supported research and development projects conducted over the past six years.

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University of California, Los Angeles

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ABSTRACT

The Center for Computer-based Behavioral Studies (CCBS) on the UCLA Campus is designed and will be developed to overcome a number of the methodological limitations blocking significant research advances in, and behavioral sciences' contributions to, the study of national policies and problems. The Center is designed around a time-shared computer system that will make its informational and technological resources avilable to behavioral scientists and policy analysts located at widely dispersed university and research centers, offering them new and powerful research, policy planning, and educational tools. A number of these tools for studying and analyzing the behavior of individuals, groups, and social-political units are specifically capable of narrowing the enormous gap that continues to exist between the policy analyst and the behavioral scientist. Essential to the development of these broad methodological and technological areas is an ongoing program of substantive research on bargaining and conflict resolution behavior relevánt to political crisis management. As the three areas of development (laboratory gaming and simulation research, inductive data analysis, and data resources management) share a systematic base of operation, the potentials for mutual support among them will be substantially enhanced. Central to all of these activities are plans based on a number of highly integrated software systems, hardware configurations, and laboratory design and equipment requirements, stemming from ARPA-supported research and development projects conducted over the past seven years.

OVERVIEW

The events of the sixties have underscored the general failure of the behavioral sciences to contribute significantly to the solution of the pressing problems of the day or to offer guidance to the decision makers who face these problems. In the outspoken view of a national advisory committee on the behavioral sciences, there is a "lack of vital social and economic information on critical issues and lack of methods for analyzing information and relating it to policies and operations."*

While there is a growing recognition of the relevance of the behavioral sciences to the range of complex decisions facing the government in domestic and foreign affairs, it has not immediately produced a new wave of social science research. The university scientists of the country have moved slowly in facing these large scale problems. Part of their reticence stems from the realization that new research directions require new methods and information resources that are beyond the capabilities of individual researchers within most university research communities.

This proposal describes the plans for a <u>C</u>enter for <u>C</u>omputer-based <u>B</u>ehavioral <u>S</u>tudies (CCBS) on the UCLA campus -- its design, phased development, and use. The center is designed around a time-shared computer system that will make its informational and technological resources available to behavioral scientists located at widely dispersed university and research centers, offering them new and powerful research, policy planning, and educational tools. The center will provide resources that will allow behavioral scientists to extend their knowledge and basic research interests

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* "Report on the Behavioral Sciences and the Federal Government," <u>American Psychologist</u>, <u>23</u>:11 (1968), p. 803.

to the study and analysis of national policies and problems. A number of these tools for studying and analyzing the behavior of individuals, groups, and social-political units are specifically relevant to help bridge the enormous gap that continues to exist between the policy analyst and the behavioral scientist, who prefers to engage in those forms of research which yield more readily to reductionist theories and existing research techniques.

The broad range of needed support can be cast into three generally defined areas:

(1) Laboratory Gaming and Behavioral Simulation Research. The aim is to provide necessary laboratory techniques so that problems embedded in real-world complexity can be studied intensively and rigorously in a controlled laboratory environment. A laboratory program is designed to break through some of the methodological limitations that currently threaten building and policy study. A variety of laboratory techniques will be developed for using the computer as an experimental tool for on-line analysis, umpiring, controlling, and recording of decision making behavior, particularly the dynamic interaction process that takes place between players and teams of players. A primary focus of such development will be to provide support for complex, multiperson simulations.

(2) Inductive Data Analysis. The need is to develop more effective tools for exploratory and inductive analysis of data that are not well understood and that may be derived from situations that do not fit the tightly structured paradigms of traditional research designs. As the sources of data become larger, more complex, and more open-ended (whether from the growing role of induction in laboratory studies or from the increased use and availability of real-world data archives), the researcher will need

new means of exploring, manipulating, and analyzing these data.

(3) Data Resources Management. The need is to develop a data resource system and associated data repository to be based on the most advanced computer analysis and data management techniques, including new procedures for information retrieval and archive maintenance. The technology we have developed for on-line data management and data analysis could provide many of the building blocks for a system to satisfy the interactive requirements and archive management for a large number of users with divergent interests. Such a system could become much more than an improved archive management capability -- it could develop into a major extension of the methods of scientific communication: in addition to retrieval and analysis, many of the informal procedures surrounding the communication of ideas and data could be incorporated explicitly into the system. Specifications for these capabilities would be established by an assessment of the needs of behavioral scientists, policy analysts, and planners and by pilot studies on existing data archives.

A common requirement for each of these proposed developments is the need for a large-scale, time-shared computer system. With the three areas of development sharing a common and systematic base of operation, the potentials for mutual support among them would be materially enhanced.

As the discussion in the next section will demonstrate, the support offered by powerful inductive analysis tools could reduce the contraints on the experimental design and data collection in simulation and gaming research; in turn, the research data collected could serve as a generating source for guiding the on-going development of the data analysis system. Laboratory research would also be supported by a data resource system

having ready-made, on-line data banks available for participants in real-world simulations; in turn, the information demands of decision makers in realistic experimental contexts could help delineate the operational requirements for the form, content, and service demands of the data resources system. Finally, and perhaps most obviously, the data analysis system would augment the data archive management functions with tools for analysis and evaluation. These do not, of course, exhaust the possibilities of mutual support; others, not now identified, will undoubtedly emerge from the demands of use where the common base of operation makes such demands reasonable.

In the most practical terms a pivotal consideration in the projected success of a research center should be its actual and perceived utility to the behavioral science community. The more closely the support developments are related by demonstrable usefulness to on-going research, the greater the likelihood that the center will be genuinely useful and used. This principle, which seems so obvious, is often lost in the process of formulating and designing research support systems. This happens in part because system users and system producers generally represent distinct groups in terms of interest and/or experience; as a consequence, highly technical and readily identifiable demands of computer and software implementation tend to take precedence over the less compelling needs of application. A practical and direct remedy for this is to make sure that the developers of the requirements of the research center are also among the major users. This strategy would be incorporated into the proposed center.

The initial specifications of requirements have been derived largely from our past project efforts to extend behavioral research to policy relevant areas through the use of computer capabilities. Since the technological, methodological, and data analysis specifications have all grown directly out of

the practically perceived needs of a substantive research program, there is a high guarantee of utility that could not otherwise be derived. For on-going developments, this close operational association between in-house, substantive research projects and resource support programs is to be continued. For the area of data resource utilization, where the requirements are less well defined, we plan to survey requirements from relevant user populations and to conduct relevant pilot studies.

PROGRESS ON PROJECT: 1 JULY 1969 THROUGH 30 JUNE 1970

Almost the entire period covering the first twelve months of the project have been completed without a definitized, final contract. Establishment of the CCBS laboratory has been delayed pending resolution of administrative and technical questions raised by the Office of the Vice President, Business and Finance, University of California. The letter contract releasing limited expenditure of project funds did not arrive at U.C.L.A. until mid-August 1969. This delayed initial hiring of personnel. An extensive technical and administrative review on the selection of the central computer configuration was not completed until mid-December 1969. Following this review, negotiations on the final contract had to be reinitiated in order to reflect the University's acceptance of a change in the central computer configuration (preliminary negotiations, following the terms of the letter contract, were based on the U.C.L.A. IBM 360/91). A revised proposal audit by the local representative of the Government Contracts Audit Agency was submitted to the contract monitor in early January 1970. Preliminary negotiations between Rome Air Development Center (Contract monitor) and the Office of Extramural Support at U.C.L.A. (representing the University) were completed in March 1970. A finalized contract was established the last week of June 1970. Implementation of the decision to acquire a PDP-10 was delayed until the contract was finalized. The amount of funding through fiscal 1972 was established at $4,448,799. As a result, the project has operated for essentially the entire first year without the enablement of a finalized contract and without authorization to acquire the central computing system and its major components of hardware and software support. Additionally, during the first half of the year nearly all planning and preliminary steps toward implementation had to be deferred until

the decision on the central computer configuration was resolved. Without definite selection of the central processing system, and without contractual authority to purchase major equipment, to subcontract for software development, or to develop project staff, a number of the activities scheduled for this period have had to be deferred or undertaken with limited staffing. Within these limitations, progress is reported in the following areas:

1. Computer laboratory support system
    a. Specification and acquisition of time-sharing equipment.
    b. Specifications of computing system software requirements.
    c. Laboratory facility design.
2. Data management and analysis systems
    a. TRACE
    b. IDEA
    c. Data resource management - archive development.
3. Laboratory gaming and behavioral simulation
    a. Simulation research.
    b. Experimental and non-laboratory research studies in conflict resolution

Rationale of Laboratory Facility Design

The overarching goal of the planned laboratory is to develop and make available capabilities for extending experimental behavioral research, particularly into areas of practical concern, through the use of on-line computer software and hardware support. Within this broadly defined objective, we plan to provide means for studying complex social-political situations with the tools ~~developed for~~ this laboratory setting.

The equipment of the laboratory system would consist of a general purpose computer and a peripheral computer, and a number of general-purpose input/output devices. These basic capabilities would be operationally augmented

by other equipment configurations (TV monitoring, video and audio recording) that would provide additional methodological options to the researcher. With these general-purpose capabilities, the whole range of functions necessary for experimentation -- the presentation of problem situations; eliciting, umpiring, and processing of subject responses; generation, routing, and display of feedback information; general administrative functions of recording, updating, timing -- could be performed. The general capabilities of the computer-based laboratory would also be substantially and critically augmented by the parallel development for data analysis, specifically designed to cope with the character and volume of data that computer-based research produces, and by the data archive and management capabilities. There would be many obvious advantages in having a general experimental vehicle with these computational and controlling powers. Some advantages would be simple extrapolations of typical methods and procedures -- performed with greater precision, accuracy, and speed. But of far greater importance would be increased capabilities permitting the investigator to develop new techniques and methods of research.

In discussing the physical facilities, computing capabilities, and electronic equipment as a "laboratory," there is no intent that it should be so narrowly conceived as to support only experimental research. In almost every regard there has been a conscious attempt to design a multi-faceted center that could support a broad range of intersecting research and educational activities -- behavioral simulation, all-computer simulation, data management and retrieval, computer-aided theory development, and computer programming.[1] Support for these various activities has been planned with explicit provision for the developmental as well as the research phases; in particular, the

hardware and software configurations have been designed as much for the activities of program development -- system programs, laboratory programs, data analysis programs, and modeling programs -- as for their use in the data gathering phases of research. While the ensuing description tends to emphasize the laboratory uses of the center, almost all of the design features reflect an attention to all planned potential uses.

1. Computer laboratory support system

The substantive areas of research in the program have been predicated on the development of a large scale time-sharing system to support the proposed computer-based laboratory and data-management capabilities. Development of the support system is an explicit and essential part of the project's responsibility.

a. Specifications and acquisition of time-sharing equipment.

(i) Central system computer selection

To satisfy central system needs, two options were available: (1) sharing the IBM 360-91 at the Campus Computing Network at U.C.L.A. or (2) using a dedicated machine to be acquired through lease or purchase. If the second option was exercised, then a selection was to be made from vendor responses to specifications drawn to satisfy CCBS requirements.

A decision was made in favor of an independent central processor rather than the use of a limited part of the U.C.L.A. computer. Specifications were drawn, an RFQ issued, and three bids received and evaluated. A purchase order was issued the final week of June 1970 to Digital Equipment Corporation (DEC) for a PDP-10/PDP-15 dual processor computing system. Approval has been requested from RADC for several modifications to this purchase order: (1) a special memory interface, (2) substitution of a new higher-speed swapping

storage device for the one originally bid by DEC, and (3) reduction in the number of terminal interface units on the PDP-15. These changes do not represent a change in system organization or function but, rather, permit the system resources to be utilized more effectively and efficiently. In particular, items (1) and (2) will greatly increase system performance. Delivery of the PDP-10 system is expected about 1 August 1970; delivery of the PDP-15 system is expected about 1 December 1970. Both processors will be interfaced to the PDP-10's 262,144 word, 1.8 usec. memory. The PDP-15 interface will have hardware relocation and memory protection similar to that in the PDP-10; control of this hardware will reside with the PDP-10, thus guaranteeing conflict-free access to memory. Since the communications interface equipment on the PDP-15 will reference memory directly by means of a separate address register, buffer, and counter for each communication channel, high speed interaction should be possible with minimal loading on either processor.

A number of potential areas of inadequacy in the system software have been identified. Changes will be required to the scanner service portion of the timesharing monitor to permit some communications to be handled by the PDP-15; there does not appear to be any cataloguing service performed by the monitor to coordinate multiple use of system resources; the dynamic debugger apparently is not protected from the programs it is debugging; there appears not to be any provision for incorporating a corrector file into a program at load time; no provision seems to have been made to permit one program to communicate with more than one terminal. Final determination of areas to be improved will be made after a more thorough study of DEC's software and hands-on experience with the system. A concurrent study is underway on

Bolt, Baranek, and Newman (BBN) "Tenex" system, which is being developed for the PDP-10 under an ARPA contract, to determine if it corrects the difficulties CCBS has identified in the DEC system and how well it satisfies other CCBS requirements. Of major concern in this study is the suitability of the BBN implementation of virtual memory. Preliminary indications are that BBN's concept does not meet the requirements of the CCBS approach to data management and inductive data analysis, as embodied in TRACE III and IDEA. In particular, BBN's virtual memory is limited to 262,144 words, whether actual memory is smaller or larger than this; paging hardware is an integral part of this implementation of virtual memory. The approach implemented previously in software as part of the TRACE III system allows for a virtual memory space limited only by the word size of the processor and neither requires nor excludes memory paging.

Temporary space has been allocated for the computing system, and a physical configuration has been worked out to fit the assigned space. A request has been made to RADC for authorization to prepare this site to accept the computing system.

The selection of a suitable high-speed printer/plotter is still being evaluated. The requirement for high speed printing with the full ASCII character set (95 printable symbols) limits the choice drastically. Currently under consideration are (1) a rotating drum impact printer by Amalex, with a top speed of 600 lpm (lines per minute), (2) an electrostatic, dot-matrix nonimpact printer by Gould-Chrite, with top speed of 4800 lpm, and (3) a photosensitive offset printing, nonimpact unit by Path, with a top speed of 1200 lpm. The latter models are quite new and relatively unproven; all have some deficiencies. Discussions are underway with Gould-Chrite and with Path to try to find solutions to these deficiencies.

A class was held by DEC for the CCBS staff on the PDP-10 processor and operating system.

(ii) Communications terminals

These were to be acquired on the basis of selection from vendor responses to CCBS specifications for softcopy terminals with high data transmission rates and graphics capability; a communications controller could be required on the basis of selection from vendor responses to CCBS specifications for terminal control and interfaced with the central system computer.

The decision to acquire an independent control processor evoked a reconsideration of the hardware for communications control; to minimize the problems of interface and integration the peripheral system controller was incorporated into the RFQ for the central processor. The selection of the PDP-10, then, was, in fact, the selection of PDP-10/PDP-15 dual-processor system with the appropriate interface between the two processors. The selection of communication terminals was made separately. Specifications for the terminals were drawn, an RFQ issued, and two responsive bids received and evaluated.[2,3]

The Computek terminal was selected. Issuance of a purchase order will be made in the first quarter of fiscal 1971. A purchase order has been prepared for 24 terminals, and authorization for purchase has been requested from RADC. Delivery is expected to start within 60 days of the purchase order and to extend over a four month period. The Computek terminals that CCBS will acquire represent a significant advance in state-of-the-art,

high-speed, large-capacity, low-cost text/graphics terminals. Based on the Tektionix 611 storage tube, the leaded-wired terminals will be able to present 51 lines of 80 columns of upper-and lower-case text (96 different characters) in less than six seconds. In addition, they can display any number of graphic vectors with a 10-bit resolution in addressability. One important new feature, developed by Computek in response to CCBS's needs, will be the first light-pen capability offered commercially on a remotable storage-tube display terminal.

(iii) Hard-copy interaction terminals.

A number of manufacturers' equipment have been examined to evaluate their suitability for use by CCBS. The desired features are: light-weight, quiet operation, at least 30 characters per second transmission, full ASCII character set output (95-96 printable characters), keyboard that permits entering all 128 ASCII codes, easy maintenance, high reliability, moderate cost. Selections have not yet been made.

b. Specifications of computing system software requirements.

Computer software support for the CCBS facility involved four major components: (1) Phase I operating system software, (2) Phase II operating system software, (3) peripheral system software, and (4) higher-order language software. Judgments and decisions about software were, of course, dependent upon, and subsequent to, hardware selections.

(i) Operating system (Phase I): Under either computer hardware option, some software modification would be required in order to provide minimal operating capabilities including I/O suspension, terminal access methods, and interrupt handling. Depending on the hardware option exercised, a decision was to be made as to whether the Phase I modifications could

be subcontracted or handled by project staff.

The selection of the PDP-10/PDP-15 hardware configuration provided a basis for judgment on operating system software. It was decided that Phase I capabilities could be achieved without extensive revision to the operating system delivered by the manufacturer and that the necessary Phase I modifications could be accomplished without subcontracting; two programmers with extensive operating system experience have been added to the staff; studies have been made of the operating system characteristics, and preliminary specifications and priorities for Phase I modification have been established.

(ii) Operating system (Phase II): In order to provide full operating capabilities required by CCBS, especially in the development of data management capabilities, extensive software and modification is required. The general requirement was for operating system-level references to a virtual memory. A decision will be made as to whether this can best be accomplished with software alone or with a hardware/software modification; an attendant decision will be made as to whether the Phase II modifications will be subcontracted or handled by project staff.

With the selection of the PDP-10/PDP-15 system, studies were initiated to explore directions of Phase II modifications. Paging hardware for the PDP-10 (the TENEX system) is being developed elsewhere under ARPA contract; the system is being evaluated for CCBS application. No final decision has been made as to the optimal means of achieving Phase II capabilities.

(iii) Peripheral system

Software modifications will be necessary to satisfy CCBS requirements for communications control, under a variety of operational conditions and with a wide range of user experience.

The selection of the Computek terminals as the primary communication devices, and of the PDP-15 as the communications controller, established the hardware context for software development. The decision has been made to produce the peripheral system software within the project rather than by subcontract. A programmer to handle these responsibilities has been added to the staff. Hands-on experience with the peripheral system will not be available until the third quarter of fiscal year 1971, but preliminary studies of required modifications have been undertaken.

(iv) Higher order languages:

Available higher order languages were evaluated and considered inadequate for CCBS applications, especially in the areas of real-time control and data management. Two higher-order language developments were planned: JOVIAL '70 and META 6.

Following the proposal plan, steps have been taken for sub-contracted production of a JOVIAL compiler. Specifications were drawn, bidders conferences held, an RFQ was issued, and three responsive bids were received and evaluated. The ABACUS Programming Corporation was selected to produce the JOVIAL compiler.[4] A purchase order for this work will be issued during the first quarter of fiscal year 1971. The decision was made to produce the META 6 compiler within the staff rather than by sub-contract. A programmer with extensive compiler experience has been added to the staff; he will also have responsibilities for monitoring the JOVIAL compiler work.

c. Laboratory facility design

The overall principle of design is to make the space maximally flexible; almost all areas would be arranged to serve a number of functions and almost all equipment would be portable thus allowing rapid reconfiguration.

Development of laboratory capability involves three aspects: (1) housing of the computer and experimental facilities (2) acquisition of laboratory equipment, and (3) production of software for laboratory applications.

(i) Housing for the CCBS:

Housing for the CCBS facilities will be developed on the U.C.L.A. campus. The physical requirements for housing the CCBS laboratory have been established, on the basis of preliminary studies, at approximately 4500 square feet of space. Existing space was available, but it must be modified to CCBS requirements. The first phase of development will involve architectural and engineering design to CCBS specifications; the second phase will involve bidding and sub-contract award, and the third phase will be actual implementation.

Plans for laboratory housing have undergone some modification in order to take advantage of any offer of better building facilities than those that were originally proposed. A floor of a new psychology building became available for CCBS use. Feasibility studies have been completed showing that the laboratory requirements of CCBS can be realized within the space available on the third floor of the new Graduate Research Unit being built for the Psychology Department and that the projected use of that space can be supported by the structure. Floor plans have been developed for space utilization. This space will provide better security, flexibility, and proximity to users than the space originally proposed. The cost associated with this better location is a delay in its availability for CCBS laboratory development. Deferral of implementation necessitated development of interim

facilities to house the computer and communications hardware during the period of initial software development. The interim laboratory space is being prepared to accept the computer system which is scheduled for early August delivery. This interim laboratory will not have any space provisions for on-line behavioral investigation; development of this capability has been deferred to the permanent laboratory since its costs would not be justified on an interim basis.

(ii) Laboratory equipment:

In addition to the computer and interaction terminals, the laboratory will require other equipment (for monitoring, recording, stimulus presentation, and information exchange) in order to provide adequate facilities for a wide range of behavioral investigation. Specifications will be made for integrating a closed-circuit T.V. system, an audio monitoring/recording system, and a general control system into the computer-based laboratory. Equipment will be evaluated, acquired, and installed in the laboratory. Acquisition of most laboratory equipment will be deferred until permanent housing is imminent. Preliminary specifications and demonstrations by potential vendors have been made in selected areas of equipment need, but final specification will be deferred until the staff position of electronic technician has been filled.

Remodeling specifications for the permanent laboratory have undergone preliminary review and costing by the U.C.L.A. Campus Architect and Engineers Office; the cost of remodeling has been estimated at $150,000; the time required for construction has been estimated at nine months from the official date of the construction contract award.

(iii) Software tool for getting into the laboratory:

If the potentials of the computer-based experimental vehicle are to be profitably exploited by the behavioral research community, provisions must be made to get the investigator into the laboratory. Past experience with our computer-based laboratories strongly suggests that although investigators generally perceive their potential, they are more strongly aware of obstacles to using the laboratory. First, the operation itself is not generally understood. Investigators may use computerized statistical services, but for the most part, they are not programmers and are unfamiliar with control systems. Second, the lead-time to see concrete results seems inordinately long. Most behavioral investigators are used to building their experiments in successive stages, with frequent opportunities for testing and modifying their procedures; by comparison, the projected elapsed times between the specification of an experiment and a computer-administered version tend to be dissuading. Third, the specification process is an unfamiliar procedure. Each experimental vehicle is a program system, requiring programming specifications to cover all interactive contingencies. The art of producing such specifications is not easily assimilated and not worth learning for the infrequent user. Altogether, these encumbrances represent a significant barrier to widespread use of computer-based laboratory resources. They can be overcome, however, by providing a means of effectively translating the investigator's requirements into operational programs.

A computer program is being developed to provide a software vehicle for laboratory researchers with little computer knowledge. It will assist them in implementing their experimental and simulation requirements as easily and

quickly as possible. The modes and content of interaction in the laboratory program have been defined; the programming system has been formulated as a five step process -- (1) gathering experimental specifications, (2) producing an interim version of the experiment, (3) reviewing and revising the interim version, (4) producing the definitive version of the experiment, and (5) executing the definitized version. Five program modules are being formulated to support these five steps; these five modules will operate in sequence as the laboratory programming system. The current (working) formulation of the programming system is structured in terms of presentation/action logic; presentations are further defined in terms of format/content, and actions are further defined in terms of operationalized response and action-sequence logic. These chained and defined procedures are related to experimental subjects in terms of states, which, in turn, are chained to define participant roles within the experimental condition. This formalization structures the operating program in a format that is foreign to research investigators, for whom it would serve poorly as a conceptual scheme for specifying their experimental designs. The initial, and in many respects most critical, problem, then, is to devise a module which will elicit specifications on the researcher's terms and translate them into the presentation (format/content) and action (response/action-sequence) logic. This is the design goal of Step I; this module has been formulated in detail, as the first to be produced. In order to mitigate the loss of operational capability entailed by waiting for the JOVIAL compiler, a decision was made to produce a limited initial version of the laboratory software in FORTRAN (which is delivered with the PDP-10 system). Implementation will proceed immediately following computer delivery.

2. Data management and analysis systems.

Inductive data analysis methods. The increasing complexity and growth of data sources require new means for the researcher to access, retrieve, edit, explore, manipulate, and analyze large data bases. This need will be satisfied through the continued development of interactive computer data analysis concepts and systems (e.g., TRACE and IDEA) to utilize their capacity for intensive and flexible scrutiny of critically defined portions of large data bases.

a. TRACE

TRACE (Time-shared Routines for Analysis Classification and Evaluation) was initiated under a previous ARPA contract. At the outset of the present contract an operational version of the program (TRACE-II) and a working prototype of TRACE-III was available on the Q-32 computer.

Experience with earlier version TRACE had shown the most powerful features of the system to be its capability to derive new measures and to reincorporate these into the data base so as to maintain associations with previous data. Since the derivation process is essentially one of writing special-purpose programs, the need for a redefinition of the objectives of the TRACE system became evident. Viewed more generally, the objective is not merely how to provide an experimenter with an analytic tool tailored to the kinds of questions raised in behavioral studies; rather the need is for a system that permits an investigator or data clerk to produce special-purpose computer programs directly -- using a language that is natural, appropriate, and easy to learn, without his having to learn anything about computer programming -- where the system assumes responsibility for, and

automatically performs, those aspects of program development which are the major sources of difficulty and error even to experienced programmers. The need is for something analogous to what has been characterized as an implicit programming system.

In existing programming systems, the major obstacle a novice programmer encounters, and a critical source of annoyance to even an experienced programmer, is the almost universal requirement that he completely define all of his current and future data structures before he ever specifies a manipulation of the data contained in these structures. A second obstacle is the need to make explicit the way these structures are to be filled initially from data stored on some medium, such as punched cards or magnetic tape. These two obstacles tend to limit the potential applications to those which can be anticipated beforehand; they are also major sources of error in programming. Other significant sources of program errors exist in 1) converting the user's indices of the data to programming indices for the data structures; 2) computing indices for cross-referencing from one part of a data structure to another or from one data structure to another; 3) maintaining associations among items of information residing in different data structures; 4) determining where, within the defined data structures, the newly-derived information should be placed; and 5) providing for branching or tree-structures logic in the manipulative portions of the system.

These major difficulties and sources of error in existing programming systems result from requiring the programmer to be responsible for functions that can be performed by a general-purpose and comprehensive data management package. By generalizing the data management capabilities of TRACE-I and TRACE-II to handle multiple data bases containing information that may be multi-indexed, it has been possible to avoid most of the constraints and sources of

error that exist in conventional programming systems. A further benefit of designing a programming system around a comprehensive data management capability is the resultant possibility of designing a language that is virtually isomorphic with conventional algebraic, logical, and statistical notation, thus greatly simplifying and speeding the process of learning to use the system. Such a language can have an extremely compact and efficient notation, permitting a considerable reduction in the number of statements required to specify data manipulations. Any reduction in the number of statements further reduces the opportunity for introducing programming errors. At the same time, however, special, guided interaction for the novice user is still provided. In accordance with the revised objectives, TRACE-III was designed to have the properties of an on-line programming system. It represents a significant extension of the earlier TRACE systems in the direction of implicit, multi-dimensional data manipulation. It permits the non-programmer user to specify on-line, special-purpose data analyses or derivations that otherwise would require the preparation of special-purpose computer programs. With TRACE-III, the non-programmer user can specify and execute manipulations or analyses in minutes or hours that would otherwise require days or weeks for experienced programmers to write, debug, and run. As with the earlier TRACE systems, the result of each manipulation is added to a common pool of information in a way that preserves associations with previous data, thus making it available for any subsequent manipulations. Since TRACE-III can be operated either on-line or in a background mode, it offers the user the opportunity to pursue his hypothesis through a series of exploratory analyses or to perform complete special-purpose or standard analyses in a batch-job fashion.

Development of the TRACE-III system is dependent on the availability of suitable higher-order programming languages (JOVIAL and META 6). The development, then, must be deferred at least until an operable (as distinguished from a complete) JOVIAL compiler is available on the PDP-10 system. In preparation for implementation, the Basic TRACE-III formulation has been refined and documented. Since the data analysis/management system is so highly dependent on JOVIAL and META 6, the Basic TRACE-III formulation provided valuable guidance in making the JOVIAL compiler specifications.

A detailed description of the structure and function of Basic TRACE-III has been written.[5] This document supplies background information on the TRACE development effort, describes the TRACE-III system organization and dynamics of its utilization in general terms, presents a formal model of data acquisition and representation that underlies the TRACE system design, and describes, with many examples, the complete set of capabilities available to a user of TRACE-III.

b. IDEA

IDEA was developed for on-line interaction on the Q-32 computer time-sharing system. It is designed for discovering and summarizing potentially interesting data models in the form of restricted tree structures for a multivariate data base. It permits the investigator to collaborate with an open-ended library of programmed heuristics in the process of uncovering and representing the structure of his data. The result of an IDEA analysis is a decision tree that graphically represents the rule used to partition a set of observations.

IDEA operates on the values of a number of variables that represent measurements taken over a set of entities such as interviewees or experimental subjects. For a given IDEA analysis, one of the variables is considered

dependent. The group observations associated with a particular entity defines a point in space that has one dimension for each variable. IDEA enables the investigator to develop a decision tree that partitions this space into exhaustive, mutually exclusive regions.

The number of potential decision trees for any interesting set of data is too large to permit an exhaustive search for the best partitions; consequently, the routines that search for structures are heuristic. They seek out a subset of candidate variables for partition at each node of the tree. These promising partitions are then evaluated by means of heuristically chosen criteria for assessing the success with which a partition can explain the variation in the dependent variable. At each node, the program recommends which independent variable to use and how its values should be partitioned; the user retains the option to choose some other variable or a different set of partitions for the recommended variable. The same process that is used at the first step in the analysis, when the entire data base or a random sample thereof is considered, is also used for subsets at lower points in the tree. Termination decisions are based on arbitrary thresholds for desired quality of fit, sample size, and improvement in quality of fit.

A limited FORTRAN IV version of IDEA is being developed on the IBM 360/91 computer to operate on the URSA system. This will make IDEA available to a wider number of users and to provide an interim version that can be used on our data prior to the availability of the JOVIAL compiler. Work on the program is limited by the fact that the 360/91 is not suitably interactive, but the FORTRAN version should be readily transferred to the PDP-10 when it is available. Ultimately, IDEA will be incorporated into the data analysis/management system in JOVIAL in a manner that permits it to function with a TRACE-III data base.

The code generated to date for the FORTRAN version of IDEA contains the basic ordinal and nominal heuristics, the data structure and logic which creates and modifies a tree structure, and the capability to sample from the data base and/or from the set of available variables. When fully debugged it will permit its user to cycle through the procedures required to "grow" a tree-structure from a given data base.

It does not yet include the capability to interact with its user via URSA. A file for this interaction has been designed and created. The routines required to read and write this file have been designed, and are being written. However, since these routines are unique to URSA (i.e. not transferable to the PDP-10) the work in this area has been given low priority. It is very likely that these routines will be ready to compile about the same time as the rest of IDEA is ready to operate, using the non-interactive mode.

The raw data pre-processed file transgenerator (a sub-program designed to provide an interface between raw data and a statistical data management system) has been successfully compiled and executed on one of the standardized raw data bases, producing a pre-processed (p-p) file.

A program designed to enable the potential IDEA user to "recode" his data (if necessary) to set the integers (0-14) which IDEA accepts was made operational on URSA.

All available code generated to date for use in the FORTRAN version of IDEA was compiled on URSA.

c. Data resource management - archive development.

The task of effective utilization of archives must be considered within the context of the inductive data analysis methods described above. The capabilities of TRACE-III, when extended and integrated into a single system, can provide most of the user services required of a data resources system. In addition to the capabilities described, TRACE-III can solve many of the technical problems associated with data archive management. For instance, the problems of how to determine the appropriate level of aggregation of data to be entered into an archive and how to compose data stored at different levels of aggregation are resolved by TRACE-III's capability to handle data at any level of aggregation and maintain appropriate associations both within and between levels. Further, the problem of standardized formatting is largely resolved by permitting the user to use whatever format is appropriate for collecting his data and to describe this format when he enters that data into the archive. The problem of specification of information in a data base is greatly reduced by giving the user the ability to reference his data symbolically.

The primary area in which additional development must now take place is in providing these services concurrently to a large community of users and still guaranteeing rapid access to, and the security of, the common pool of data on which they all operate and to which they all contribute. These general capabilities have to be translated into specific system design requirements through an assessment of the needs of current archive users and potential users of the CCBS facilities and by pilot studies to evaluate methodological innovations. The design of such a system must provide the flexibility for relatively direct extension and upgrading as existing demands change and new ones develop.

The work in data resource management has been confined largely to the software aspects of the problem. A review of the state of the art was undertaken

as the initial step in program formulation. Current operational data management systems, such as ADMINS, DATA-TEXT, DATANAL and TROLL, etc., have been studied.[6] These reviews have suggested potential extension to JOVIAL '70 to improve its data manipulation for archive management; and operating systems are continually evaluated especially with regard to archive requirements for virtual memory software.

3. Laboratory gaming and simulation research.

Plans are being developed for a behavioral studies laboratory program to break through some of the methodological and conceptual problems that currently limit the ability of laboratory simulation as a tool in both theory building and policy study. A variety of laboratory techniques developed for our experimental bargaining studies are being extended for simulation studies. These include the use of the computer as an experimental tool for on-line analysis, umpiring, controlling, and recording of decision making behavior, particularly the dynamic interaction process that takes place between players and teams of players. A primary focus of such development would be to provide support for complex, multi-person, international relation simulations. Implementation of the substantive research program involves: construction of high quality scenarios, development of simulation methodologies including techniques for incorporating remotely located teams, establishment of a panel of professionally knowledgeable players, compilation of a real world data bank and development of sub-model routines, development of methodologies for structured simulation play; and implementation of educational support techniques.

a. Simulation research.

Background. Simulation exercises are being conducted at a number of research centers for the study of international relations, political-military strategy, and allied topics. Two divergent approaches have been used in these

gaming efforts. In policy-oriented gaming where credibility and realism are emphasized, data have not been systematically recorded and analyzed, methodologies employed are typically unevaluated, and experimental control is deemed unnecessary except for constraining departures from realism. In research-oriented gaming, where theoretical and methodological issues are of primary concern, superficial representation of reality and the use of unskilled players have led to extensive criticism and charges of triviality. In either case, because these games are administered, played, and observed manually, they are severely limited in the level of detail and volume of data that can be gathered and analyzed. Consequently, whether policy- or research-oriented, such games are unable to deal with a number of important questions, some of which are so fundamental as to bear on the validity of the games themselves.

After carefully reviewing this area, we have evolved a research plan that attempts to join both approaches and to eliminate a number of the limitations associated with each. We believe that the use of on-line computer techniques in such complex games might well allow for a significant breakthrough. In particular, an attempt is being made to realize jointly the objectives of the theory-oriented researcher, and the more stringent demands for credibility and relevance of the policy-oriented practitioner, through our newly developed capabilities to administer, monitor and analyze games automatically.

In our program of research we plan to continue efforts to integrate five goals: 1) develop computer simulation methodology for laboratory exercises, 2) identify and study those issues of international relations theory and general decision behavior in conflict-of-interest and crisis management situations, 3) illuminate important issues in American foreign policy, 4) incorporate real world data to help specify variables and control activities in the simulation setting,

and 5) develop all computer simulation models based on the theory and data generated in the laboratory simulation studies.

Proposed simulation scenarios will continue to focus on some of the central issues of American foreign policy today -- the factors influencing the degree, form and effectiveness of US-USSR involvement in local conflict.

A key problem of the United States foreign policy in the next decade will be the extent to which the United States can, in future crises, take actions that are commensurate with its conventional and nuclear power, its economic strength, its scientific and technological status, and its interests in the outcome of the crisis. We are concerned with studying the factors which permit or constrain the United States and the Soviet Union from taking action in a set of representative crisis situations. Most particularly we are concerned with the dynamics of deterrence and commitment processes in these such crises.

While pursuing the detailed development of particular scenarios, we are attempting to set forth a theoretical framework that raises questions about the dynamics of great power involvement. The hypotheses of interest are being used to shape scenarios and the simulation format as much as possible without compromising their policy-validity and their utility for policy analysis. Within this framework our simulation research has proceeded in a number of directions.

(i) <u>Completed Mid-East 1973 Simulation.</u>

We have focused first on achieving a laboratory simulation that avoids or minimizes the use of procedures that trivialize or simplify issues so that the simulation activities and results would not be viewed as superficial by policy experts. Under the prior ARPA contract this approach was initiated using a series of four manual simulation exercises using a Mid-East crisis scenario that differed primarily in terms of the levels of sophistication of the participants.

In each run, four teams (three members each) represented Egypt, Israel, the United States and the Soviet Union. Analyses, some completed and some still in progress, are designed to identify the differences in team behavior and to relate these differences among the groups in mode of problem definition, methods of problem attack, utilization of information, degree of contingency planning, extent of perceived constraints, sensitivity to adversary position, concern for the forms and expectations of international protocol, etc. These differences are proving to be illuminating not only in a substantive sense but for subsequent developments in simulation methodology. Many features of these runs have now been summarized in a published paper.[7] Certain basic similarities and differences in style and content among the teams in the same nation roles, in response to the initial scenario and to the unfolding action of the game, are described.

During the most recent reporting period, work has continued on the completed transcript of the taped verbatim record of one of these runs with RAND/Faculty participants. These efforts have evolved in the two related directions described below.

(ii) General Inquirer content analysis of the Mid-East scenario, team position papers and game moves.

The RAND/UCLA records were encoded for content analysis by the General Inquirer using the Stanford Political Dictionary. This undertaking is permitting us to compare the results of the content analysis program with the results of other analyses, and to determine its utility for policy/simulation generated data.

A preliminary computer analysis of the messages and position papers for each of the four nation teams has been completed. Using this total of approximately 4000 words, perceptions and actions of each actor are being

analyzed from a perceiver, actor and target perspective along three standard semantic differential dimensions employed in earlier studies: evaluation (e), potency (p) and activity (a). These dimensions have also been combined to yield indices of threat perception $\left(T=\frac{\text{negative e + positive p}}{\text{all e + all p}}\right)$ and cohesion as a factor in commitment. Two indices of perceived cohesion between nations are being compared: 1) the similarities of national perceptions of other nations and 2) the degree of reciprocity between nations in their evaluations and views of one another.

A modified version of Theodore Newcomb's A-B-X model of interpersonal communications suggests that relations between two actors may be judged in terms of their attitude toward a common external object (nation) salient to both perceivers. To the extent that perceptions of the common object are similar (in either positive or negative terms) the perceptual behavioral relationship between the two perceivers will be positive. To the extent they are dissimilar, the relationship will be negative.

Both hypotheses are being tested for perception of qualities and perceived performance of each perceiver toward the other. An attempt is also being made to examine certain hypotheses developed by Zinnes that deal with relationships between the perceptions of and perceived reactions to "threats" by national actors.

In general, our findings seem to correspond with those of Zinnes. Some other preliminary, provocative findings have surfaced: 1) The USSR was viewed by all other nations as the most threatening nation, the USA as the least threatening; 2) each local power saw its own superpower as more threatening than the superpower of its opponent; 3) both local states viewed their own actions toward each other in relatively non-threatening terms; 4) At the same time, the USSR perceived Israel's threat to the Soviet Union in more hostile terms than

Israel perceived its own threat to the USSR; 5) using common perceptions as an index of cohesion, there seems to have been a greater degree of cohesion in the Soviet-UAR alliance than in the US-Israeli one.

These preliminary findings will be checked for their consistency in the analysis of the data generated in the three other Middle-East simulation runs.

(iii) The role of commitment processes in defining foreign policy behavior.

This effort has concentrated on developing a framework for generating and evaluating theoretical insights from the RAND/UCLA transcripts. We have focused on the general area of the significance of commitments in the relationship between the principal belligerents, Israel and Egypt, and their patron superpowers, USA and USSR. In particular, we are interested in the effects on these commitments of the acquisition of nuclear weapons by Israel. We have sought to determine the nature, strength and communication of commitments by the superpowers to the smaller powers; i.e., how they differ in terms of the following dimensions: explicitness and formality of declared commitments, strength of actual commitments (as perceived by the superpower patron, by its local ally, by the latter's local adversary, and by the other superpower, the interests underlying the commitment and the motives behind the particular communication of the commitment); and the symmetry/asymmetry in the respective superpower commitments.

Translating these concerns into more specific questions: To what extent, for example, do the major-minor power partners agree or differ in their understanding of the nature and strength of the commitment? Are there any misreadings of degree or kind of superpower commitments by adversaries as a result of implicitness of commitments? How does Israel's acquisition (in the game) of a nuclear capability change the nature, strength and communication of

these commitments?

In attempting to determine precise answers to these types of questions we have continued to modify a scale and associated sets of structured queries for use in interviews with game participants and other interviewees. The scale enables us to determine the strength -- and others' perceptions of that strength -- of commitments in terms of the probable level of response to a given level or range of action or contingent circumstances.

Of the several dependent variables regarding superpower commitments to an alliance or coalition relationship, our main concern thus far has been with determining the "strength" or willingness of the superpowers to honor defensive commitments against threats to their local allies. This has entailed formulation of hypotheses about how defensive alliance commitments are challenged or provoked and how "strength" of response to that challenge can best be measured.

We are exploring the hypothesis that challenges to the commitments both superpowers have to their allies increase with the greater threat that such challenges pose to the effective military control of the local ally's heartland. This standard for ranking commitment challenges should be distinguished from other possible ones - particularly those defining commitment challenges according to degree of destructiveness or casualties incurred by the ally or even the likelihood of his defeat in a war for limited stakes. We have further hypothesized that of the various ways in which "strength" of the superpower responses to that commitment challenge could be measured (the willingness to incur, for example, human, military, economic, domestic or international political costs), the most meaningful test of strength is that of risking or engaging in confrontation with the opposing superpower. More

precisely, the hypothesis is that the supreme cost against which the defense and promotion of interests associated with a defensive commitment is measured is by the risk it poses to nuclear war. Thirdly, we have hypothesized that the risk a given commitment response poses to a confrontation with the opposing superpower increases with the threat such an action poses to control of the local opponent's heartland.

We have been conducting a series of structured interviews to test these hypotheses about the provocativeness of commitment challenges and the strength of commitment responses. This has been part of a more general effort to develop a scale by which perceptions of the strength of the respective superpower commitments among the superpowers themselves and their local allies can be measured. An attempt will be made to relate findings from this study to related ones obtained from the content analysis of the protocols.

(iv) Plans for a book on scenarios for simulation exercises

It is surprising that although simulation exercises are finding wider usage, practically nothing has been written on how to prepare good scenarios, nor have any systematic proceedures been developed to assist the scenario designer in organizing information, materials and concepts. As a consequence, most scenarios are designed on a hit-or-miss basis, with the implications for playability, representativeness, and relevance to theory and policy concerns left to intuitive decision.

The purpose of this book will be to provide general and specific guidance on scenario development so as to contribute to an improved quality of gaming. The book will be a manual on how to conduct simulations, on procedures, record keeping, control problems, role playing, debriefing, etc. But most importantly,

it will suggest and illustrate a building block approach to scenario construction.

On the basis of theoretical and policy considerations, a set of about 10 alternate future world (set in a specified time period) will be selected and described in sufficient detail to give as a background for the study of a similar number of characteristic crises or problems. The latter, superimposed on the former in various combinations, will make it possible for each investigator to construct, from a wide variety of simulation possibilities, scenarios that are tailored to his needs. Characterizations of a variety of national regime types will further increase the uniqueness of focus that may be achieved. The plans for this project are at the preliminary stage of development.

(v) <u>Formulation of a set of simulation-testable propositions in deterrence theory</u>.

In the next phase of our laboratory simulation, we are also exploring the field of deterrence theory as it relates to U.S. involved crises in the third-world area. We are checking this effort by comparing simulation results with what has happened in similar crises in the real world (Korea, Quemoy, Vietnam). We are in the process of formulating a set of simulation-testable propositions for studying detterence processes and a companion list of questions designed to help us explore how these propositions operate under conditions of successful and unsuccessful deterrence. Questions are as follows:

<u>Explanatory questions</u>. (1) Why do deterrence successes succeed? And if we can develop the typology of deterrence failures further, (2) How do types of deterrence differ with respect to relevant independent variables, especially commitment?

<u>Diagnostic questions</u>. (3) How do defenders who correctly judge that deterrence is about to fail do so? (4) How do defenders who correctly diagnose the incentive structure of the attacker do so? (5) Would an analytical forecasting or a "single best guess" approach give the defender a better chance

of guessing that deterrence is about to fail?

Prescriptive questions. (6) What are the action implications of different diagnoses of imminent deterrence failure? (7) What are the best reinforcing tactics to use if it appears that deterrence is about to fail? (8) What is the relative value of threat as against assurances, payments, or compensation?

Two research approaches to these questions are being developed. One pursues a predictive theory through a set of propositions attempting to characterize: a) the violation of the *status quo* by an initiator, b) the reply by the responder, and c) the outcome(s) in terms of success or failure in a single or extended series of rounds. Timing (latency) and intensity of each actor's response are used to define basic definitions and through inertia, learning, and predictability of the opponent, to account for the behavior of each. A second approach explores a rational theory (normative) what is the "best" response. A "good" deterrence theory would be investigated through simulation by exploring what kinds of people under what kinds of group procedures are able to operationalize the theory effectively. In this approach the team is trained in a theory to explore the conditions of its effectiveness. Dr. Alex George at Stanford University and Dr. David Wilkinson at UCLA are serving as consultants on this effort.

(vi) A Mid East scenario for 1974 and a proposal for a one-team game.

The purpose of the proposal is to create a one-team game which eventually can be put on a computer and which will determine the level of Arab-Soviet endangerment of Israel that would motivate an American decision to give large-scale direct military assistance to Israel. The effort will be an attempt to see if a flow-chart approach using a yes-or-no answer technique can be combined to produce a relatively inexpensive international relations game requiring only limited personnel and supervision and which will afford greater control for

research purposes.

The game would be organized around a pre-game scenario setting the stage for future developments in the Middle East. There would also be a game scenario specifying at reasonable intervals a series of Arab-Soviet actions which progressively threaten Israel's security and ultimately its survival as a state. Control would present to the U.S. team at each interval a description of the situation created by a new Arab-Soviet action. A request for a specific amount of U.S. military assistance to Israel will be made, and a yes-or-no answer required of the U.S. team. After the answer is given, the team would be asked to give an explanation and rationale for the decision. The combination of situation statements, requests for assistance, and rationales for replies would produce a complete game record. The game would go on until the United States decided to give large-scale direct military assistance to Israel or until the latter's national security was clearly undermined.

The scenario would incorporate a bias; i.e., it would assume that the steps taken by the Soviet Union in the Middle East since 1955 are following a pattern toward the exercise of greater influence in the area. It would assume that the Soviet Union wants to reopen the Suez Canal to facilitate its shipping, and is linking up its policy activities in this area with those being undertaken in the Indian Ocean area. The game will require large-scale direct Soviet military assistance to the Arab nations for the announced purpose of forcing Israel back to her pre-1967 boundaries and implementing the UN resolutions of November 22, 1967, which were supported by the United States. The essentials of this scenario were developed in the New York Times for June 5 and June 28, 1970, by C. L. Sulzberger and George Ball.

A draft of a Mid East Scenario 1974 has been prepared and is currently undergoing critical review by the staff.[8]

(vii) Development and improvement of software and quantitative data for the refinement and exercise of two predictive models of international conflict.

This project at Stanford University under the direction of Professor Robert North, has been supported under subcontract at the suggestion of Dr. Davis Bobrow, former director of ARPA Behavioral Science.

The present report describes North's Lateral Pressure Model and clarifies a definition of the Resource Demand portion of this model of international behavior. In two parts, it (a) operationalizes North's demand index (Population x Technology)/Resources, and (b) simplifies the complicated derivation of a Lateral Pressure expression presented elsewhere by Lagerstrom and North. The results of both (a) and (b) agree qualitatively and intuitively with North's development, and the results of (b) agree exactly with Lagerstrom and North. A copy of this memorandum is attached.[9]

Emphasis during the reporting period has been on cleaning up data already in hand, gathering new data and developing and exercising the lateral pressure model.

Data Collection

The project's major data base currently extends from 1870 to 1914 for six countries and from 1916 to 1966 for seventeen countries. The 1870-1914 attribute data set (originally collected at two year intervals) was subjected to final cleanup procedures. Further refinements of the data base were made, including a more detailed series of trade data for 1870-1914, national budget data for 1946-1966, and an extensive set of U.S. military budgets and men under

arms for 1946-1966. It was discovered that yearly data points were essential for some analyses, so the additional data points were collected for the relevant variables in the 1870-1914 data set.

Yearly data have been collected on raw materials and manufactures exported and imported for Germany and Britain (1871-1913), and for Japan (1905-1939), with which to test the lateral pressure model. For the period 1946-1968, two sets of economic data were collected (distribution of foreign investments and aid dispersed and received) for the U.S., Japan, the U.S.S.R., and the Chinese People's Republic. A vast amount of data has been collected for the indicators of violence. The collection of suicide and homicide data for 1870-1967 (at yearly data points) was completed. Another measure of violence (war casualties) was gathered for 17 countries for over 60 wars. Approximately 85% of these new variables are in machine-readable form.

Thematic "Salience" Analysis

Keypunching of 11 "Speeches in Reply" from British Parliamentary records, 1870-1914 are being completed. Speeches from the Throne in the German Reichstag, 1871-1913, are being prepared for keypunching.

b. Experimental and non-laboratory research studies in conflict resolution.

Like most areas of behavioral science, the study of conflict resolution is not monolithic and is not susceptible to any single research approach. The conditions of conflict and processes of resolution can be more or less abstracted, variously represented, and studied by a number of methods. The simulation approach, because of its complexity, particularly needs to be closely interrelated at many levels with other techniques of investigation, both to clarify its findings and to serve as a direct source of hypotheses. It is necessary,

then, that the research program continue to range widely in its approaches to problems, from paper-and-pencil situations to computer-based experimentation. In particular, we plan to continue two lines of investigation in support of the simulation activities: 1) our earlier program of experimental studies in the new computer laboratory, and 2) SCENQUEST studies.

(i) Experiments in bargaining and negotiation processes.

These studies continue to investigate bargaining and conflict resolution behavior in situations where parties had interests in conflict as well as interests in common; that is, where they were mutually dependent in the pursuit of otherwise opposing goals. In such situations, the bargainers frequently employ tacit means of communication, proceeding primarily through actions and maneuvers rather than through direct exchange of explicit communiques; they are able to impede one another, and to inflict loss or harm on the other party; they are frequently unclear about the values and power of the other party. Under such conditions, which breed mutual distrust, how do negotiators succeed in mutually influencing one another to contain or resolve their conflict? What are the characteristics of the exchange of moves and signals that lead to unilateral advantages or successful joint resolution? Can the properties of the bargaining context, or characteristics of the parties in the conflict, be identified as critical influences on the resolution process?

A final report is in preparation of an experimental study on tactical problems in implementing a cooperative relation.

Much has been written about emotional factors (hostility, face-saving, etc.) as barriers to the cooperative resolution of conflict situations, but very little attention has been paid to the role that cognitive or judgmental factors may play. Even in the simple choice situation of the Prisoner's Dilemma game, the

development of a cooperative relationship <u>can</u> involve some difficult and complex practical judgments, and in this process there is latitude for some dysfunctional cognitive behavior -- the sort that would be self-defeating with regard to cooperative aims. The player who wants to establish a cooperative relationship, and meets initial resistance, must decide whether it is in his best interest to continue to try to bring the adversary around, or whether instead to defend himself against exploitation. This is a difficult judgment to make, and, as the interaction continues, there are occasions for second thoughts, doubts, hedging, and even reversal; sometimes these are justified, sometimes not, but always there is the possibility for oscillation of judgment, and goals, which would affect the behavior and perspective of the adversary (who presumably is rendering and reviewing his own practical judgments). Added to, and compounded with, this judgmental interplay is another cognitive demand: given a decision to try to bring the adversary over to cooperation, there is then a need to decide on the best tactics. This, too, is a difficult judgment, and one susceptible to doubts and oscillation of judgment. In all, some matters of cognitive difficulty may stand between the cooperatively inclined bargainer and the ultimate development of the cooperative relationship. These facets of cooperative resolution were to be systematically examined in a computerized Prisoner's Dilemma experiment.

We have created an unusual "shaper" condition to permit us to observe how difficult it is, in purely tactical terms, for one player to "shape" another to a cooperative solution . This condition is achieved by limiting the shaper's strategic goal to that of achieving a cooperative end result -- eliminating the shaper's need to defend himself against short-run losses. His payoffs are defined solely by his success in bringing the other player around to cooperative

play in the closing period of play. The shaper's tactics are left open-ended, and he is free to use the "carrot" or the "stick" or a combination of these. What tactics he does select, how consistently he applied them, and their end effectiveness were all examined. Along with these questions, we have also explored the extent to which a relative power (payoff) advantage for the shaper weakens the resolve or willingness of subjects to resist conversion, and alters the shaper's tactics. Finally, we examined the question of how this live shaper compares with a simply defined tit-for-tat program.

Results indicate that shapers who most consistently use a combination of "carrot" and "stick" tactics are most effective, and that shapers who use only one of these consistently is less successful. However, the frequency with which shapers responded to exploitation immediately following a trial of joint cooperation was highly correlated with success in achieving cooperation at the end of the game. These and other results and their implications are discussed in the report.

An earlier report on the effectiveness of pacifist strategies has been published.[10]

(i) <u>SCENQUEST - A scenario questionnaire technique for studying in-process phenomena in conflict resolution.</u>

Many <u>in-process</u> bargaining phenomena cannot be studied easily in experimental game situations because they occur rarely, or follow unique patterns of antecedent events, or require more extensive subjective analysis than can be easily obtained during the experiment. The SCENQUEST approach, based on a combination of standard techniques, affords the experimenter a convenient, low-cost means of collecting data on a wide variety of situations

that require control and standardization of antecedent events. An example of such a situation is a player's sudden shift to aggressive moves in a condition that had been stable and characterized by cooperation, and where no outside triggering event could be detected.

In the SCENQUEST approach, the experimental subject is given a specific opening or ongoing situation or game. The synopsis is in dramatic, real-life terms or in bare-bone, analytical ones, and may concern such situations as a husband-wife confrontation, a prisoner's dilemma payoff matrix, etc. The synopsis gives a summary history of the events and decisions made by both parties, up to a given point. The subject reads the scenario from the point of view of one party in the situation; he is then asked to respond as if <u>he</u> were in the situation with the history as it is given and in the designated person's place. He then records his response on a questionnaire form. This procedure contrasts with role-playing where a person is asked to adopt <u>another's</u> attitudes, opinions, etc. The respondent here is situation-playing.

A current SCENQUEST study explores a number of determinants of the perceived size of conflict at the opening phase of bargaining. Variables identified for analysis include size of stake in the bargaining, divisibility of issues into separable bargaining units, amount of opportunity for exchange of bargaining offers within a negotiation encounter, number of negotiation encounters, and degree of asymmetry of outcomes. Game materials, instructions and recording forms have been developed for these variations. A 2 x 2 x 2 x 2 x 2 experimental design explores the effects of these variables singly and in combination on a set of 57 dependent measures. Six replications of the design (192 subjects) have been completed and preliminary analyses are underway.[11]

FUTURE PLANS

Plans for the ensuing period of the contract, (July 1970-June 1972) would, of course, be a function of the originally proposed program of research and the project progress to date. Generally the plans-to-completion and the originally proposed program remain coincident despite the delays experienced in the first year of the project; but realization of the project goals will require accelerated effort in many areas in the remaining two years. Based on current developments the projected plans for the Center are the following:

Central computer system: The PDP-10 is scheduled for delivery in August with 32 K of loaned 1.0 μsec core (K=1024). This core will be exchanged for 128K of 1.8 μsec core in mid-September. The remaining 128-K of 1.8 μsec core, the PDP-15, and the special system interface are scheduled for delivery in December. Thus, the total basic central and peripheral processing systems will be operational within the next six months. A study culminating in a decision on virtual memory hardware is planned in the next nine months; initial steps of implementation are projected within the next fiscal year. Studies and decisions on peripheral hardware, notably a printer, a plotter, and hard copy terminals are scheduled for the next six months. In summary, the total system hardware configuration should be complete in terms of design commitment within the next twelve months, and, excepting the virtual memory hardware to be implemented early in the third year, the system should be completely operational at the beginning of the third year.

Peripheral system hardware: The entire complement of communication terminals (24) is scheduled for delivery in the next six months. This will coincide with the installation of the high-speed communications controller so the entire communications system should be operational prior to January 1971.

The exception to full operational capability is the light-pen; a prototype will be included with the first delivery of the terminals; this will be evaluated and production model specifications will be made sometime before January 1971; light-pen capability for all terminals should then be implemented before June 1971.

Operating system software (Phase I): A concerted effort to upgrade the operating system will occupy most of the software staff in the next eight to ten months, so that the basic Phase I system will be completely definitized and largely implemented coincident to the delivery of an operable JOVIAL compiler. The advent of an operable JOVIAL compiler is the most significant milestone in the planned software development since it represents the first application programming capability in a steady-state operating context. After this milestone is achieved, Phase I software work will be confined to maintenance and selective upgrading.

Operating system (Phase II) software: The planning and preliminary formulation for Phase II operating system will occur during the next mine months. This study will be dependent on, but not confined to, the study on virtual memory hardware. Contingent on that hardware decision and schedule of implementation, work on the Phase II operating system will begin in the last quarter of fiscal year 1971. This work will continue through the third year (fiscal 1972) with initial operational capability projected for January 1972 and upgrading to follow on.

Peripheral system software: Work on the software interface between the PDP-10 operating system and the peripheral system will begin with the delivery of the PDP-10 system and will be accelerated with the delivery of the first communication terminals. Development of peripheral system software will commence with the delivery of the PDP-15 communications controller. Operational capability should be achieved within the next 8 to 10 months. (A teletype

capability will be available essentially from the time of the first stage delivery of the PDP-10). The feasibility will be evaluated of developing a PDP-15 simulator on the PDP-10 to permit development of peripheral system software prior to delivery of the PDP-15. Such an approach offers the possibility of saving as much as two months in achieving an operational capability. Maintenance, upgrading, and special interface projects are programmed for the ensuing period.

Higher order language software: The subcontract for the JOVIAL compiler will be issued in the first quarter of fiscal year 1971; an operable compiler will be produced within the first ten months of the contract; the compiler will be extended and upgraded during the ensuing eight months; and the full compiler will be maintained under contract for the ensuing 24 months. During the fourth quarter of fiscal year 1971, a version of the META 6 interpreter will be written in the JOVIAL language. An operable version of META 6 is projected for the first quarter of fiscal year 1972.

Laboratory housing: It is anticipated that the interim laboratory will be ready to receive the computer in September 1971 and barring unforeseen circumstance the present housing should be adequate without further modification through the period of interim use. The permanent laboratory is in the preliminary design phase; costs estimates and preliminary designs should be ready in September; the new floor will be ready for internal modifications by June 1971, and ready for occupancy in July or August, and the laboratory functional by September. This schedule may be accelerated since the permanent building may be ready for occupancy sooner than now anticipated. Full operations must await the completion of initial support software, currently projected for the second quarter of fiscal year 1972.

Laboratory equipment: Final specifications and evaluation studies will be made in the next six months; and procurement will proceed over the ensuing six months, to outfit the permanent laboratory. For the remaining period of the project the equipment configuration will be maintained, replaced, upgraded and augmented as needs arise.

Laboratory software: The initial version of the "entry" module of the laboratory programming system will be produced in the next six months. The "entry" module of the laboratory programming system is the one that is used to elicit the investigator's preliminary experimental design specifications. The initial language of implementation for the module will be FORTRAN IV; the decision as to whether the program will eventually be converted to JOVIAL will be contingent on its efficiency and compatibility with other system components; the choice of FORTRAN for the initial version permits immediate implementation since the PDP-10 computing system is delivered with a FORTRAN compiler. This package will be empirically tested, upgraded and augmented during the ensuing six months; this will provide an operational version for initial use in the laboratory. Following implementation of the "entry" module, it will be empirically tested for its effectiveness, i.e. its ability to elicit an investigator's experimental design specifications. The mode and content of the "entry" interaction between the investigator and the computer-based experimental context will be evaluated on the one side in terms of user satisfaction, and on the other side in terms of the comprehensiveness of the specifications that are elicited. These empirical studies will antedate the actual availability of the permanent laboratory; it is thereby anticipated that the software will be developed and available for use as soon as the permanent laboratory is ready for occupancy. The improved version in FORTRAN IV or in a conversion to JOVIAL will incorporate redesign features prompted by

operational use. The redesigned JOVIAL version will be produced in the ensuing six months with maintenance and upgrading scheduled for the remainder of the project.

Data analysis/management system: The formulation of the Basic TRACE III has been completed; coding will begin in the third quarter of fiscal year 1971 with component checkout of the initial system scheduled for completion within three months of the delivery of a reliable version of JOVIAL. System checkout is scheduled for completion in the third quarter of fiscal year 1972. Formulating for extensions of Basic TRACE III will be completed by the end of 1971 with coding to follow directly after the completion of basic TRACE III and checkout projected for the second quarter of fiscal year 1973. Maintenance and upgrading are scheduled for the remainder of the project. IDEA will be transferred to the PDP-10 in the first six months of fiscal year 1971; parallel with its operation in FORTRAN IV it will be converted to JOVIAL and interfaced with the Basic TRACE III data base system; this integration is scheduled for the third quarter of fiscal year 1972.

Data archives system: Some studies and evaluations in advance of formulation have already been completed; others will be completed in the next six months so that formulation can begin before the end of fiscal year 1971; formulation is scheduled for completion before the third quarter of fiscal year 1972, then, depending on the implementation of virtual memory capabilities, production of the data archives system will begin toward the end of fiscal year 1972.

<u>General Inquirer content analysis of the Mid-East scenario, team position papers and game moves</u>: Work will continue on the syntactical uncoding of the data of the other three simulation exercises and the results of these exercises will be compared with and combined with the data from the RAND/UCLA run for a summary report. Work will also continue on improving the Stanford dictionary, and on expanding the capabilities of the retrieval functions of the Inquirer II program.

<u>The role of commitment processes in defining foreign policy behavior</u>: A report will be made on the results obtained using the newly-revised scales in interviews with game participants and other subjects not participating in the exercises. These findings will be related to the ones obtained from the content analysis of the Mid-East simulation protocols. The scales of preceived commitment will subsequently be employed for data gathering in the one-team games.

<u>Plans for a book on scenarios for simulation exercises</u>: The organization of the volume on simulations and the writing of some of the chapters will be undertaken. A conceptual scheme will be developed to assist in the selection of the subsets of alternative future worlds that will be developed for the construction of scenarios. National regime types will be characterized to increase the potential focus of the "constructed" simulations. Prototypical scenarios will be generated to illustrate the technique.

<u>Formulation of a set of simulation-testable propositions in deterrence theory</u>: A plan for testing the identified set of deterrence theory propositions will be formulated. Particularly regarding normative theory, the mode of testing will be primarily by simulation; procedures for operationalizing these tests and relating the results to deterrence theory more generally will be derived and documented. Decisions as to when the tests will be implemented will depend both on the testing requirements and the schedule of simulation

capabilities.

A Mid-East scenario for 1974 and a proposal for a one-team game: The draft scenario will be revised during the next period and its suitability as a one-team game, and as a vehicle to test the data theory propositions will be completed. An analysis of the flow-charting of relevant decision points and contingencies will be undertaken. This design formulation will be used as one of the specifications to test the efficacy of the "entry" step in the laboratory software that is being developed.

Development and improvement of software and quantitative data for the refinement and exercise of two predictive models of international conflict: The data collection and theory development will continue along the lines described. Specifically, the new yearly data will be incorporated into tests of the lateral pressure model, the indicators of violence will be completely available in machine-readable form, and the speeches from the 1871-1913 period will be keypunched for salience analysis.

Experimental Gaming: A final report of an experimental study on tactical problems in implementing a cooperative relation is in preparation. Analyses of data from previous laboratory-based experiments will continue and results will be reported. Preliminary plans for experiments will be formulated in anticipation of the development of permanent laboratory facilities. These will be used as test cases for the "entry" module of the laboratory software system.

SCENQUEST - A scenario questionnaire technique for studying in-process phenomena in conflict resolution: The administration of the scenario questionnaire will be continued until twenty replications of the basic experimental design are obtained. These will then be combined with the existing data in preparation for an analysis of the full set of data.

Professional Conferences, Presentations and Activities:

Al Cooperband attended the TENAR (ARPA users of the PDP-10 system) meetings hosted by Bolt, Beranek, and Newman, Inc., Cambridge, Mass., January 1970.

Gerald H. Shure presented a paper entitled "On-line Computer Techniques for Behavioral Studies" at the Quantitative Political Science Meeting, Monterey, California, 29 January 1970.

Gerald H. Shure lectured on "Simulation Methods" to the Graduate Fellow Program in Urban Planning and Development, U.C.L.A., 17 February 1970.

Gerald H. Shure presented an address entitled "On Simulation Approaches to Complex Social Processes", at the Political Science Colloquim, U.C.L.A., 20 February 1970.

Gerald H. Shure was chairman of the Panel on Simulation and Gaming, at the International Studies Association (West), San Francisco, California 1 March 1970.

Gerald H. Shure served as an observer and consultant on simulation exercises at Industrial College of Armed Forces, and National War College. The exercises used a modified version of the Mid-East scenario prepared in our research program. Principal consultation at the exercises was with Commander Leo Parent, 9-11 March 1970.

Stewart Shaffer, regional representative to the National ACM Council, attended the Atlantic City ACM meetings. He also represented CCBS at the DECUS meetings, and SIG SOC meetings, also held in Atlantic City, April 1970.

Members of the software staff attended an informal seminar on TENEX by Dan Barbrow of Bolt, Beranek, and Newman, held at U.C. Irving, May 1970.

Gerald H. Shure presented a paper entitled "Nuclear Weapons in the Mid-East: A Laboratory Simulation," at the Peace Research Society, Cambridge, Mass., 4 June 1970.

Gerald H. Shure assisted graduate students in the development of a simulation study (POWER) on the location of an electric power plant in a community. The project was awarded first prize in the Engineering Faculty Friends' Competition.

Gerald H. Shure served as a reviewer for the Journal of Social Issues, the Journal of Experimental Social Psychology, Computer Abstracts, and for NSF/ACDA research proposals. He was also an occasional reviewer for the Journal of Social and Personal Psychology.

Visitors and Demonstrations:

Dr. Bernard Sussman, SGMA (Societe de economie e du mathematique applique), Paris, France was briefed on the Center research and data management program. 19 March 1970.

Ivan Sutherland briefed the software staff on the developments of the Ivan Sutherland display system. April 1970.

A lecture on "Interactive Computer Development for Behavioral Science Research" was given by Gerald H. Shure to an IBM sponsored four for distinguished European computer scientists. 28 April 1970.

Professor William H. Starbuck of Cornell and John Dalton of S.M.U. were briefed on the the Center research program. 20 May 1970.

Lt. Commander Ted Kramer and Colonel Wayn Hawk of JWGA were briefed on the Center program in simulation and data management, including a demonstration of TRACE and IDEA. 1 June 1970.

Pat Langendorf of EMIRD/RADC visited the Center for an informal, three-day review of the research program. The primary focus of the discussions was efforts to coordinate with other government sponsored projects to avoid redundancies and increase interproject communication. 15 July 1970.

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7. Shure, G.H., DeWeerd, H.A., and Meeker, R.J.: Nuclear weapons in the middle east: a laboratory simulation. Peace Research Society (International), 1970, in press.

8. DeWeerd, H.A.: A Middle East Scenario 1974 (draft). 24 July 1970.

9. Lagerstrom, R.P.: Progress Report, Memorandum 70-ICI-L, Institute of Political Science, Stanford University, 30 April 1970.

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11. Shure, G.H., Lanto, S.S.: Subject Materials For Administration of One Version of Negotiation Experiment: Instruction Booklet, Quiz on Negotiation Experiment, Pre-experiment Questionnaire, U.C.L.A., May 1970

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